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Spectral Weighting of Binaural Cues: Effect of Bandwidth and Stream Segregation

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Introduction

Anecdotally, normal hearing listeners can attend to a single sound source in the presence of other sound sources by forming auditory objects. This is commonly referred to as the cocktail party effect. It is known that listeners use, among others, interaural disparities in time and intensity (referred to as ITD and ILD, respectively) to localize a sound source.
An open question is, however, how ITD and ILD information is integrated over frequency, and how streaming affects auditory object formation using interaural disparities. ITD weighting functions were previously derived using inverted sensitivity thresholds of narrowband signals (Stern et al., 1988). This method does not take binaural interference (McFadden and Pasanen, 1976) into account and might not be applicable to more realistic broadband signals.

Hypothesis

It is hypothesized that binaural information is integrated over frequencies in the binaural system to lateralize sounds (Buell and Hafter, 1991; Woods and Colburn, 1992) using a spectral weighting function. Furthermore it is hypothesized that this weighting is not fixed but can vary depending on the signal properties and on the acoustical context of the sound.

Method and Stimuli

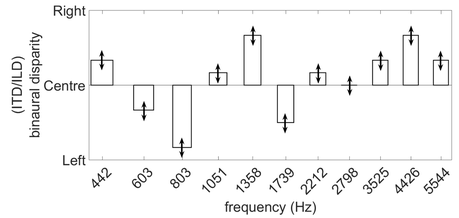
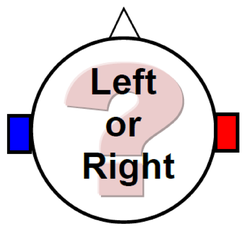


Figure 1: 11 one-ERB wide noise bands with centre frequencies from 442 to 5544 Hz with 1-ERB wide gaps. The binaural disparities (ITD/ILD) are roved over stimuli. The level of the noise bands is 60 dB SPL per ERB.

- 11 ITDs (-500µs : 100µs : 500µs)
- 11 ILDs (-5dB : 1 dB : 5 dB)

- Stimuli presented via equalized via headphones (HDA200)
- 1I-2AFC (left/right decision task)



- Weights derived with a logistic regression analysis
  - 11 inputs (binaural disparity)
  - Binary output (left/right lateralization)
  - Probability described as

$$P = \frac{e^{\beta_0+\beta_i x}}{1+e^{\beta_0+\beta_i x}}$$

  - With β being the weights leading and the linear model

$$y = \beta_0 + \beta_i x_i$$

Experiment 1: Static condition

- 10 normal hearing listeners

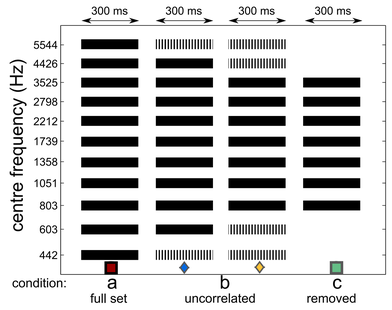
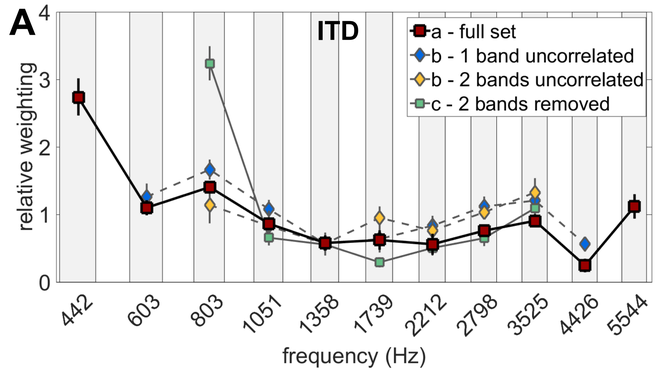


Figure 2: Sketch of the subconditions in experiment 1. The black bars represent the noise bands with binaural information (ITD or ILD). The dashed bars represent interferers with uncorrelated noise.

4 subconditions were used to investigate the influence of the most outer frequency bands. In **a** all 11 noise bands contained ITD/ILD information, in **b** the 1 or 2 most outer bands were set to uncorrelated noise and in subcondition **c** the 2 moster outer bands were removed.



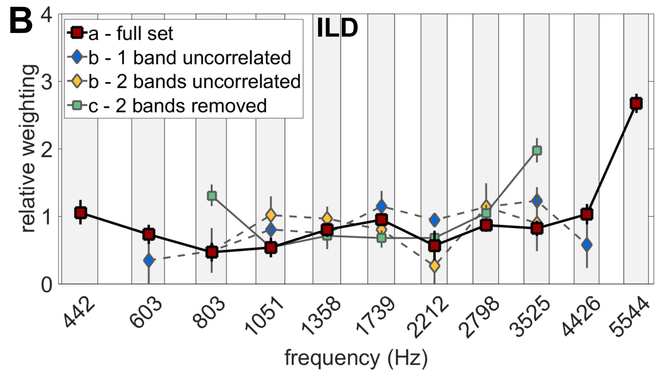


Figure 3: Perceptual weights (mean ± standard error) for ITD (**A**) and ILD (**B**) determined with 10 subjects. The large and small squares represent the conditions with 11 (red) and 7 (green) noise bands, respectively. The diamonds show the conditions with noise interferers on the single and double most outer edge bands. The weights are normalized relative to their mean value.

- Spectrally most outer bands receive highest weights
  - Lowest frequency band for ITD
  - Highest frequency band for ILD
- Reduction of overall of stimulus bandwidth results in change of weights
  - ⇒ New spectrally most outer band receives highest weight
- Uncorrelated noise on most outer bands does not lead to change in weights
  - ⇒ Flat weighting function (equal weights)

Experiment 2: Streaming condition

- 6 normal hearing listeners (subgroup from experiment 1)

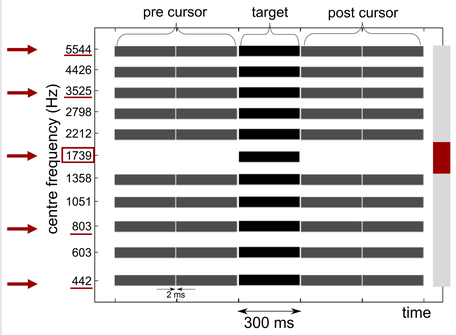
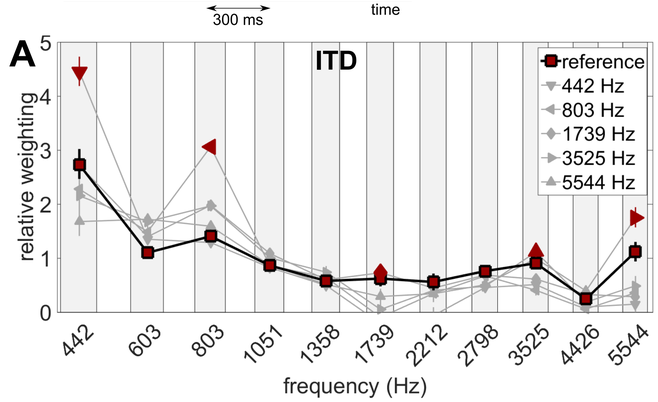


Figure 4: Sketch of the time/frequency representation of the signal used in the streaming scenario with a on-frequency of 1739 Hz (red box). The arrows/lines indicate all used on-frequencies from this experiment. The black bars represent the target signal as used in the static experiment. The grey bars represent the pre-/post cursors and are correlated noise, interaurally out of phase.

on-frequency
off-frequency



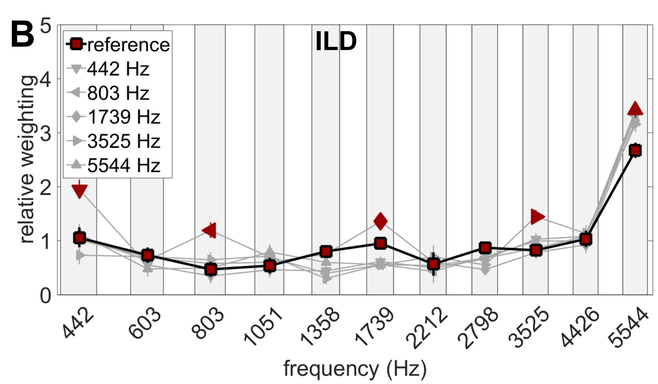


Figure 5: Perceptual weights (mean ± standard error) for ITD (**A**) and ILD (**B**) determined with 6 subjects. The black line with red squared markers is the reference condition as in the static experiment. The grey squares without frame indicate the streamed conditions and the red highlighted ones the on-frequency weights. The weights are normalized relative to their mean value.

- Streaming leads to increase of on-frequency weight
- Off-frequency weights mainly decrease
- Effect only at low frequencies for ITDs
- Increase for all frequencies for ILDs

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Discussion and conclusions

- Results obtained different to what would be expected from the duplex theory

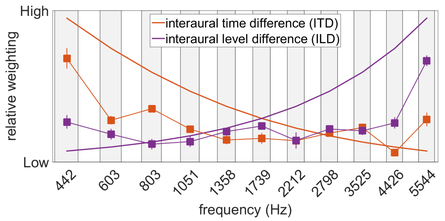

Figure 6: Perceptual weights for ITD and ILD (boxes) as in **figure 3** compared to the physical accessibility of the cues as in the duplex theory.

- Results different to weights obtained by Stern et al. (1988)

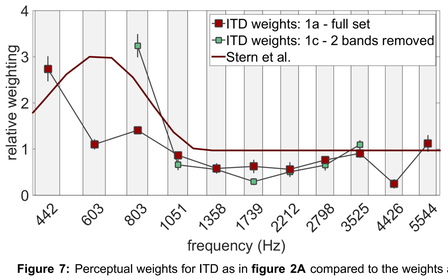

Figure 7: Perceptual weights for ITD as in **figure 2A** compared to the weights as described by Stern et al. (1988). The weights from Stern et al. are scaled to fit the range of the here obtained weights.

- Spectrally most outer bands play a special role
- Weighting of frequency bands depends on spectrally near content
  - Content on only one spectral side leads to high weight (condition 1b)
  - Uncorrelated noise on the other side does not change the weight (comparing condition 1a to 1c)

  - ⇒ Listener's judgement of lateral location of sound is biased by binaural cues on the most outer frequency bands

- Streaming leads to an increase in weights
  - ⇒ Release from interference?
- Increase in weight only when binaural information available
  - At low frequencies for ITD
  - At all frequencies for ILD

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